Biodegradable Thermoplastic Natural Fiber Composite

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Problem Statement

Composites cannot be easily recycled or reused. They usually end up in landfills where they do not degrade for several decades. Composite materials have added a significant part to the ever-growing worldwide plastic litter problem.

Biodegradable polymers are expensive and most of them are not suitable for making composites. Commercial production of fully biodegradable composites combining biodegradable resins with plant fibers is very limited. Problems exist regarding cost, quality, property, and application.

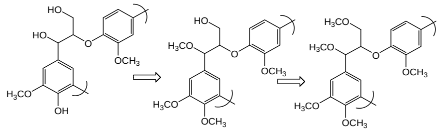
Lignins are a major polymeric component in all vascular plants (~30%). They are the resin that glues the cellulosic fibers together in wood (the natural composite). Like all biopolymers, lignins are biodegradable. Enormous quantities of very low cost industrial lignins could be available for use from the pulping industry and the emerging biorefinery industry. However, the development of value-added lignin-based products has met only limited success. Byproduct lignins are usually burned to produce electricity at an equivalent fuel value of about $0.03/lb.

Although lignins are thermoplastic in nature and have some desirable thermal properties, industrial lignins (that have been derived from plant materials) are usually brittle and weak. Unless ways can be found with which their materials properties can be suitably modified, industrial byproduct lignins do not exhibit enough mechanical strengths suitable for use directly as resin for making composite.

Technology Description

We proposed that chemical modifications are necessary to transform lignin structures to obtain more desirable materials properties for use as resin. It has been found that alkylated kraft lignins exhibit mechanical properties similar to polystyrene [1]. In this project we will explore several chemistry routes that are expected to bring about significant changes in lignin's materials properties. Conditions for achieving the designed chemical reactions will be established. To obtain adequate tensile and shear strengths, effective polymeric additives and plasticizers will be found and formulated to produce lignin-based thermoplastic resins. The resins are then blended with natural fibers to form a fiber reinforced composite.

Changes in chemical structure can significantly affect polymer's physicochemical properties and mechanical properties. Below shows an example of chemical modification of lignins by methylation. The effects of methylation on lignin properties depend on the degree of methylation, which is reflected in the frequency of new methoxyl groups along the lignin polymer chain and the extent of methylation occurred to different hydroxyl groups in the lignin structures.



1. Li, Y.; Sarkanen, S. *ACS Sym. Ser*. **742**, 351 (2000).

Expected Results

Formulations based on chemically modified lignins will produce thermoplastic resins suitable for making biodegradable composites.

Synergy effects are expected to result from compositing lignin thermoplastic resins with fibers. The strengths of the resins could be significantly improved by fiber reinforcement in the composite as a result of increasing strength at the crack tip so that higher stress is needed to break the material. Therefore the composite should be much stronger and tougher than the resin itself, which could overcome the drawbacks of lignin polymeric materials.

Thus the composites will feature lignin resin as the continuous matrix with the filling natural fibers reinforcing the strengths of the resin. The composites will be different from conventional wood based composite materials such as plywood, particle board, and fiberboard. They will be melt-processable and can be molded to various sizes and shapes. They can be used in many structural and non-structural applications such as "green building" materials, furniture, automobile parts, packaging and casing for consumer products, and disposable containers.

The composites will be low cost since they can use the byproduct lignins from industrial processes such as pulping and the emerging biorefineries. Low cost and biodegradability will be the driving forces for the composite's future commercial success.

Potential Environmental Benefits

Large scale production and use of fully biodegradable composites will reduce the harmful effects of plastic wastes to the environment. The thermoplastic natural fiber composites can be recycled, reused, and composted at end-of-life.

The success of the project will provide a practical use of a vast and largely untapped polymeric materials in lignins as building materials. This could potentially save large amounts of wood and lumbers. The development of biocomposites from abundant and renewable natural resources provides a strategic alternative to the depleting petroleum. It will contribute to increasing national security and protecting the environment.

The success of the project could solve a critical problem in lignin utilization for the emerging biorefinery industry. Current cellulosic ethanol technologies have been developed to the point of break-even in economics. Value-added lignin products will have a positive impact to the overall economics of the cellulosic ethanol processes in terms of increasing revenue and profit, and could bring about the breakthrough necessary for their commercialization and sustain long term growth. This could contribute to the national goal of replacing 30% of gasoline with renewable fuels by 2017.

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